US006114621A

United States Patent [19]

Tachino et al.

[11] **Patent Number: 6,114,621**

[45] **Date of Patent: *Sep. 5, 2000**

[54] **PHOTOMULTIPLIER WITH MAGNETIC SHIELDING CASE**

[75] Inventors: **Masumi Tachino**; **Hidehiro Kume**; **Suenori Kimura**; **Takashi Goto**, all of Hamamatsu, Japan

[73] Assignee: **Hamamatsu Photonics K.K.**, Hamamatsu, Japan

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

[21] Appl. No.: **08/924,651**

[22] Filed: **Sep. 5, 1997**

[30] **Foreign Application Priority Data**

Sep. 6, 1996 [JP] Japan 8-237018

[51] **Int. Cl.**[7] **H05K 9/00**

[52] **U.S. Cl.** .... **174/35 R**; 257/680; 257/681; 257/659; 257/660; 361/800; 361/816; 361/818; 250/216

[58] **Field of Search** .... 257/680, 681, 257/659, 660; 174/35 R; 361/800, 816, 818, 861; 250/216

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,567,948	3/1971	Oke et al.	250/216
4,152,745	5/1979	Eul	361/146
5,130,531	7/1992	Ito et al.	250/216

FOREIGN PATENT DOCUMENTS

0 571 201	11/1993	European Pat. Off. .
0 722 182	7/1996	European Pat. Off. .
1547659	11/1968	France .
58-45524	3/1983	Japan .
6-11572	1/1994	Japan .
6-109635.	4/1994	Japan .

OTHER PUBLICATIONS

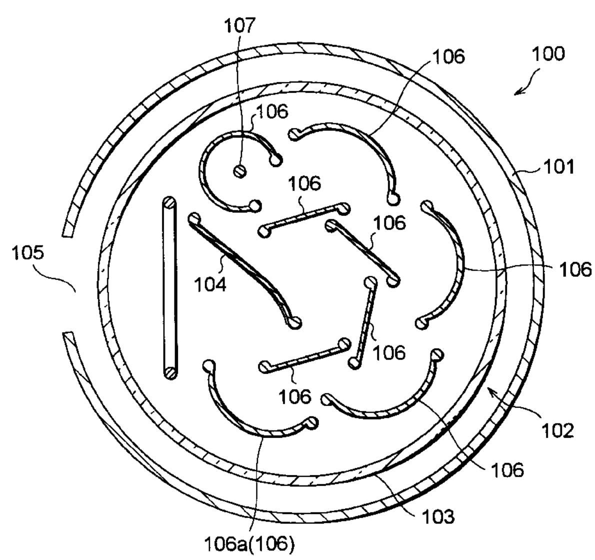
"Photomultiplier tubes, Hamamatsu Photonics Catalogue" Aug. 1995, Cat. No. TPMO 0002E04, Japan XP002095966.

Primary Examiner—William A. Cuchlinski, Jr.
Assistant Examiner—Ronnie Mancho
Attorney, Agent, or Firm—Pillsbury Madison & Sutro LLP

[57] **ABSTRACT**

The present invention relates to a magnetic shielding case comprising a structure for improving the uniformity in light receiving sensitivity of a phomultiplier while maintaining sufficient magnetic shielding function, and a light detecting apparatus including this magnetic shielding case. This apparatus comprises a photomultiplier and a magnetic shielding case accommodating the photomultiplier. In particular the magnetic shielding case comprises a housing having an opening for transmitting therethrough light to be detected which is directed to the photomultiplier; a lens element for guiding the light to be detected into an effective region on a photocathode; and a positioning structure for placing the photomultiplier at a desired position with respect to the lens element.

8 Claims, 14 Drawing Sheets



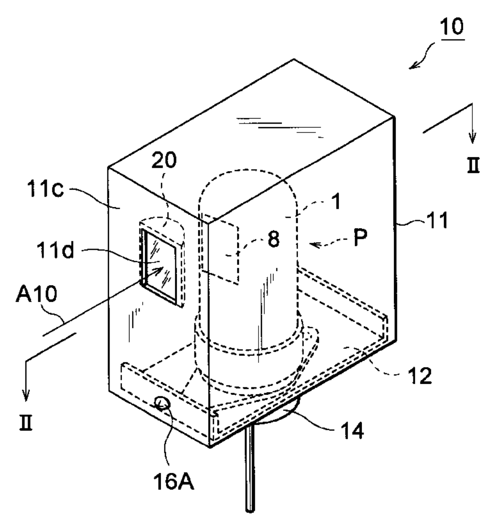


Fig.1 (PRIOR ART)

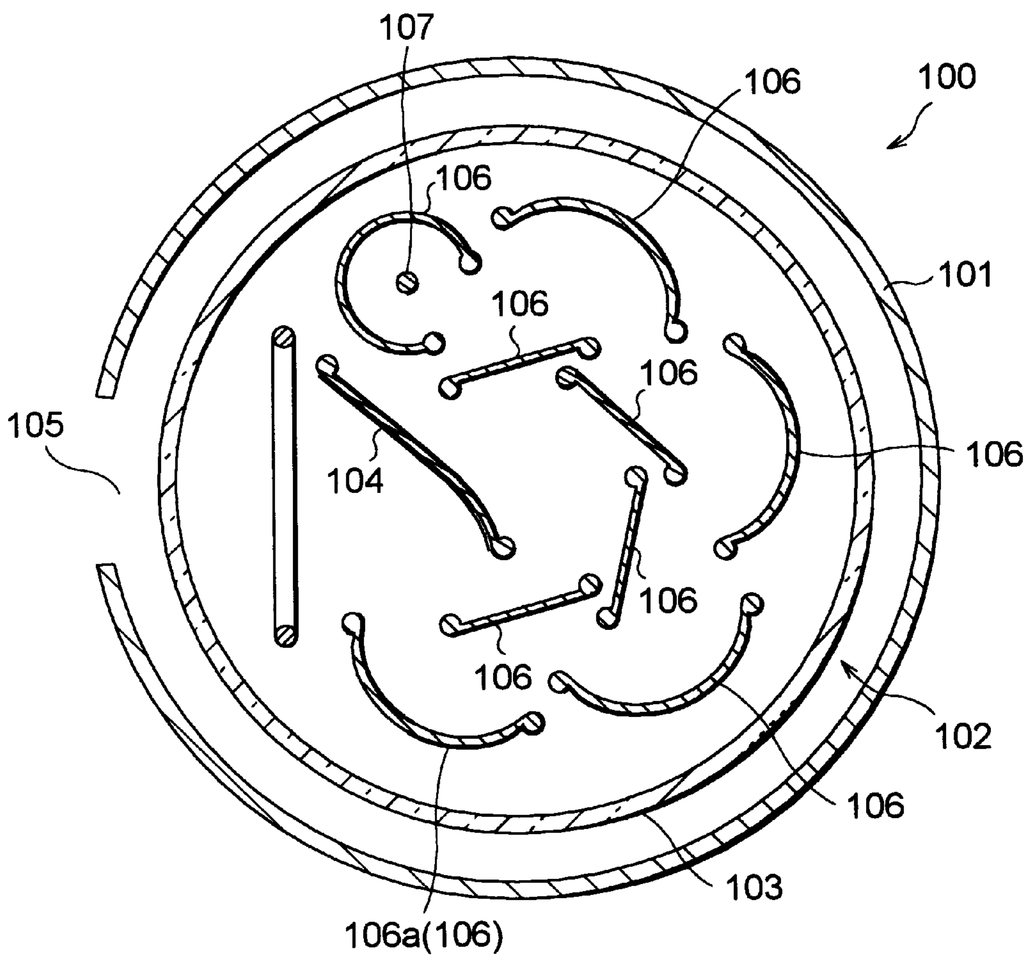


Fig.2

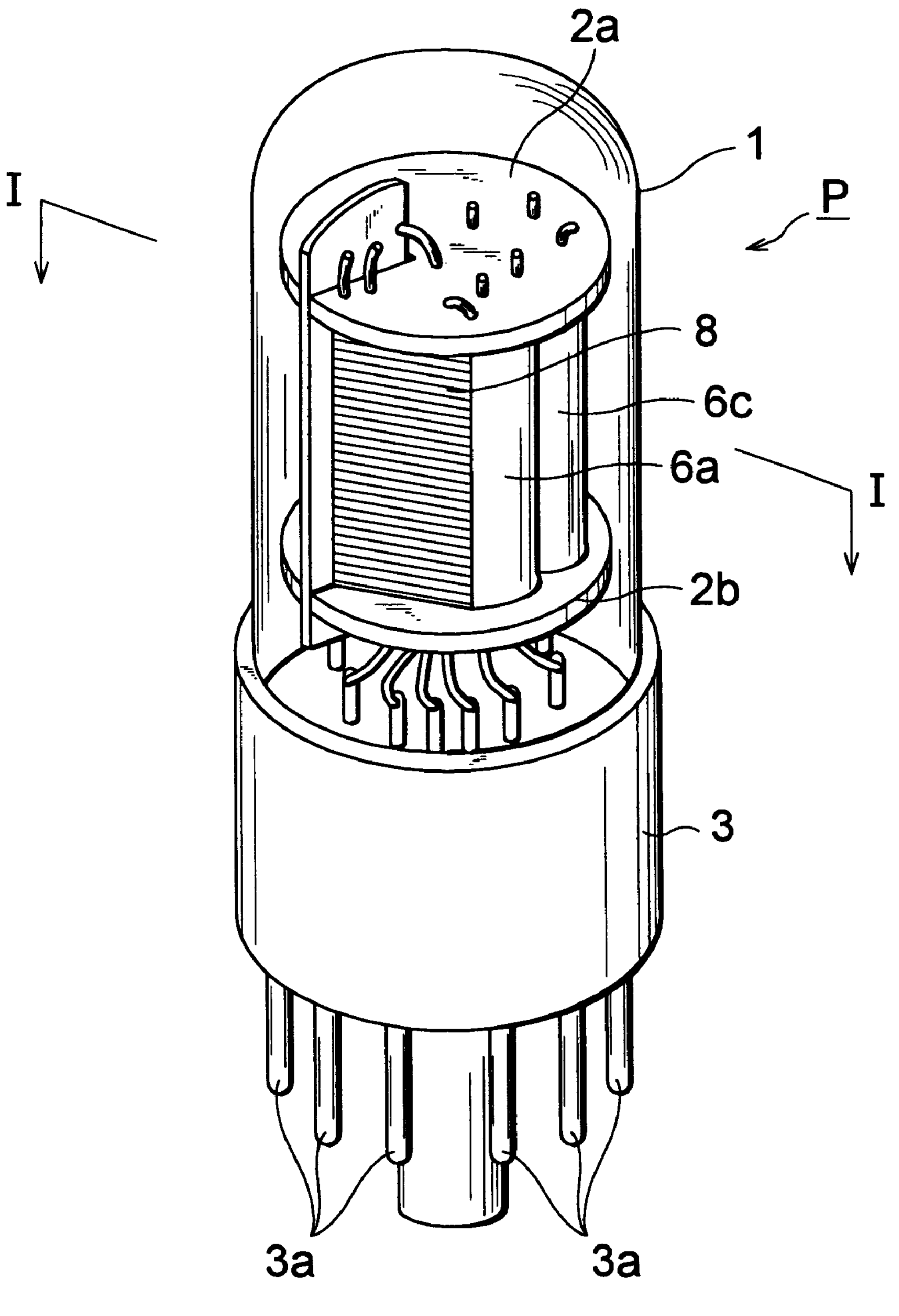


Fig.3

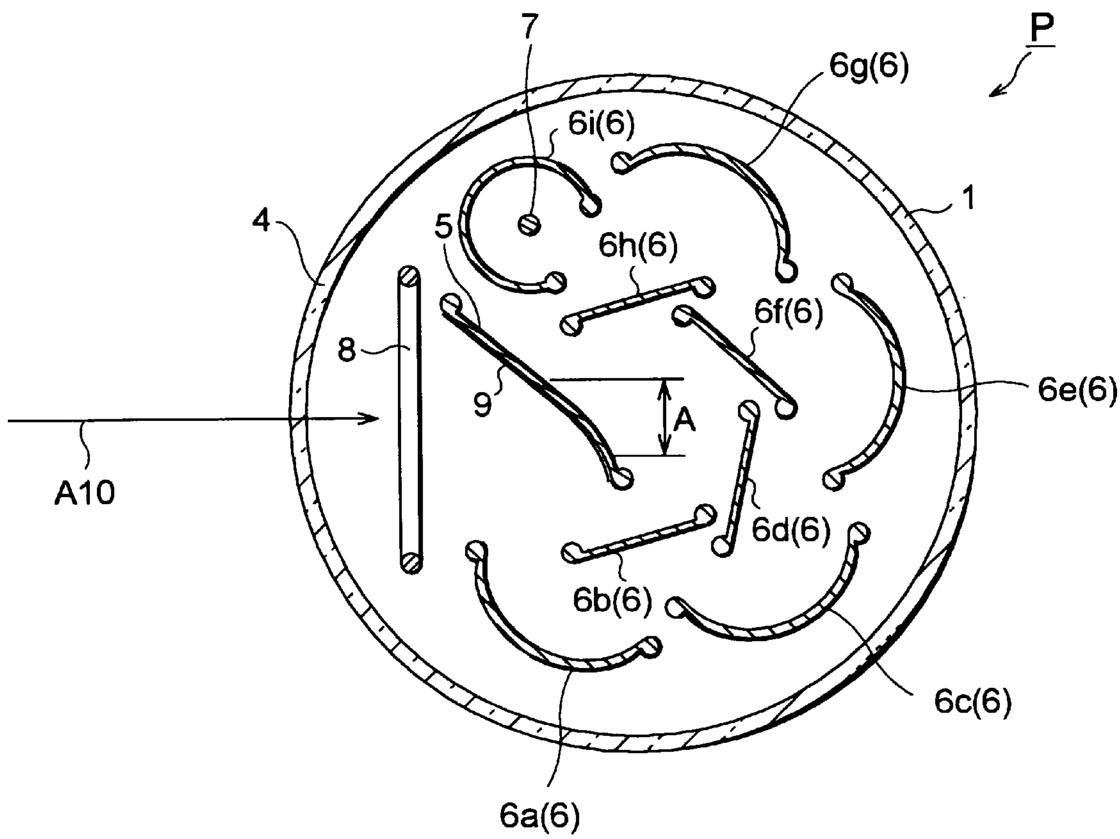


Fig.4

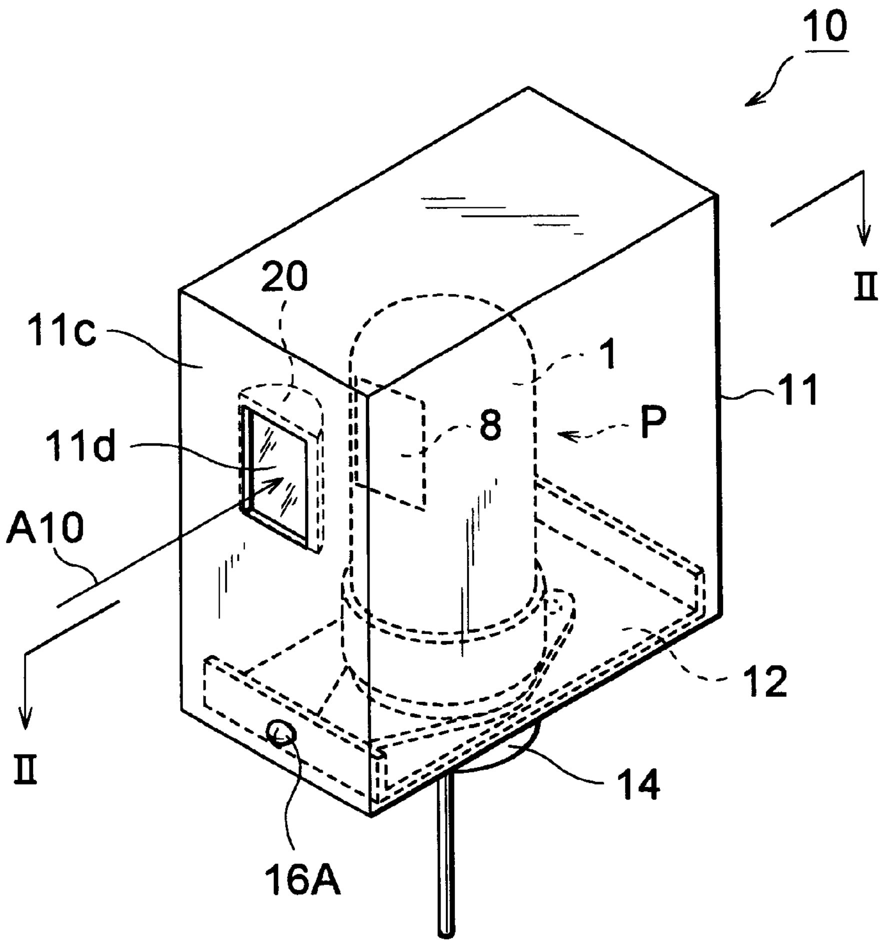


Fig.5

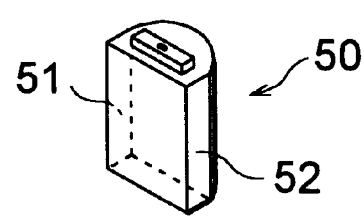
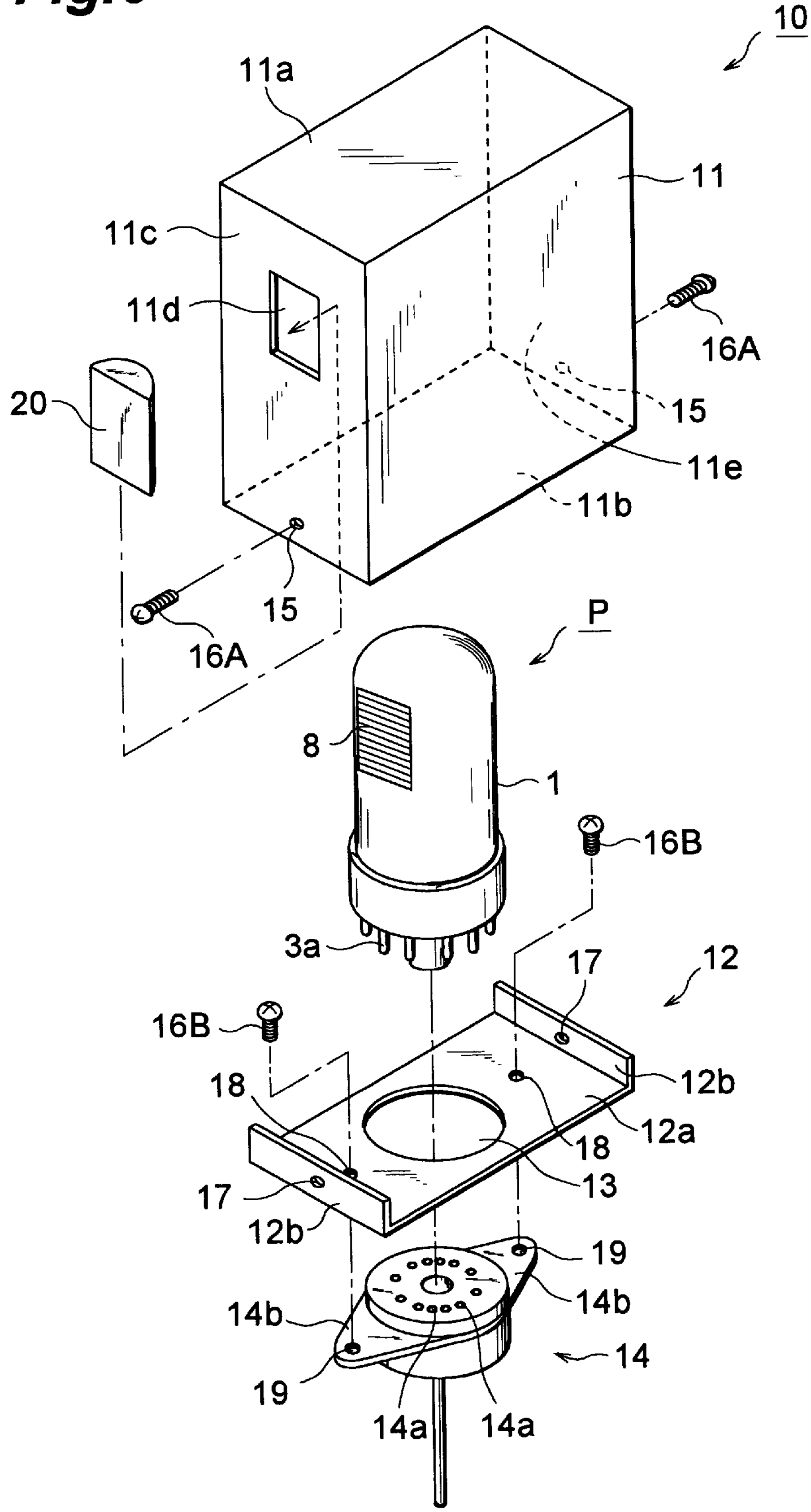


Fig.6


10
11a
11
11c
11d
16A
20
15
11e
11b
15
16A
P
8
1
16B
3a
12
17
16B
12b
18
12a
18
13
17
12b
19
14b
14b
14
19
14a
14a

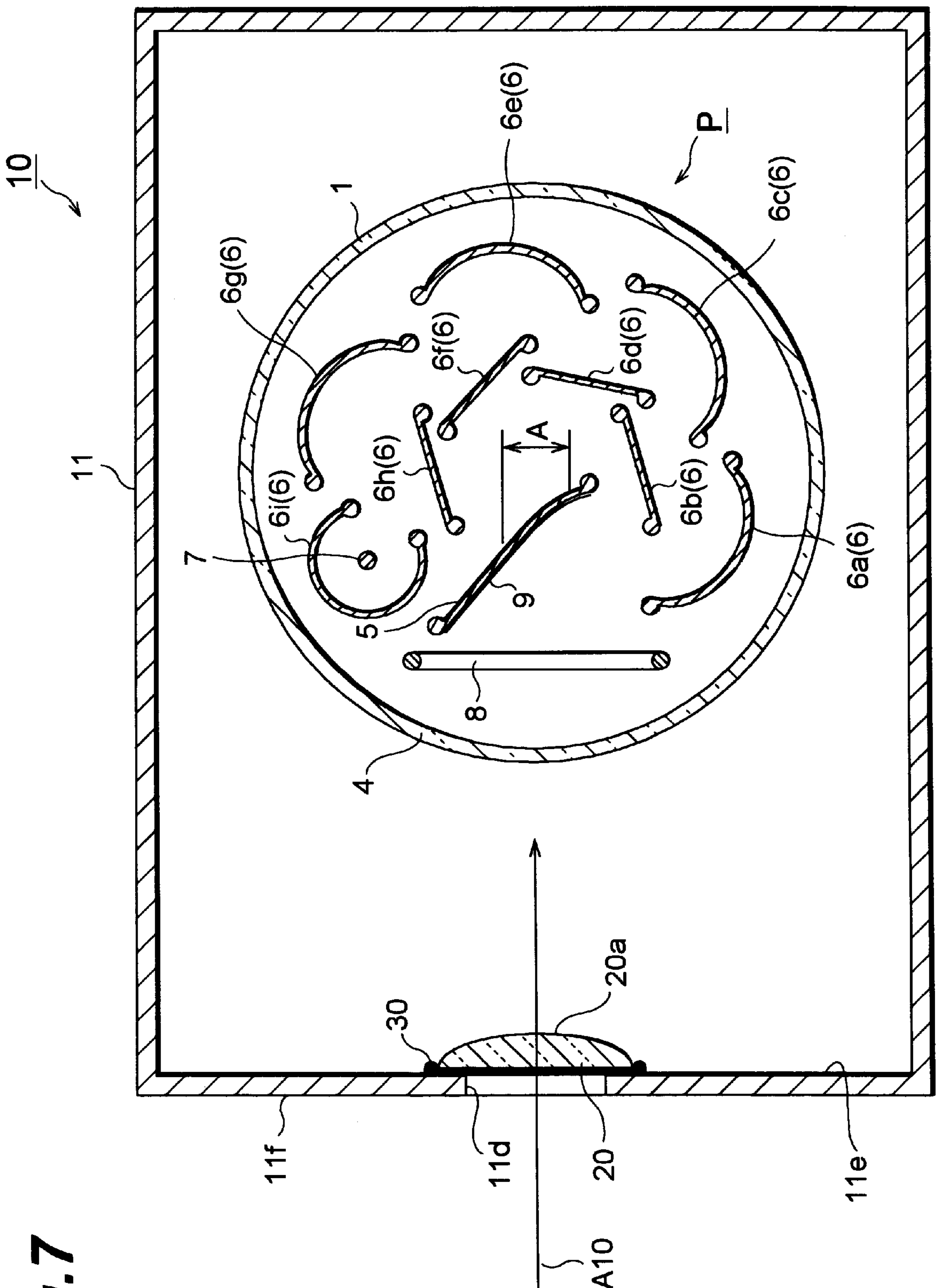

10
P
1
6e(6)
6c(6)
6g(6)
6f(6)
6d(6)
A
11
6h(6)
6b(6)
6i(6)
7
9
6a(6)
5
8
4
30
20a
11f
11d
20
11e
A10

Fig.7

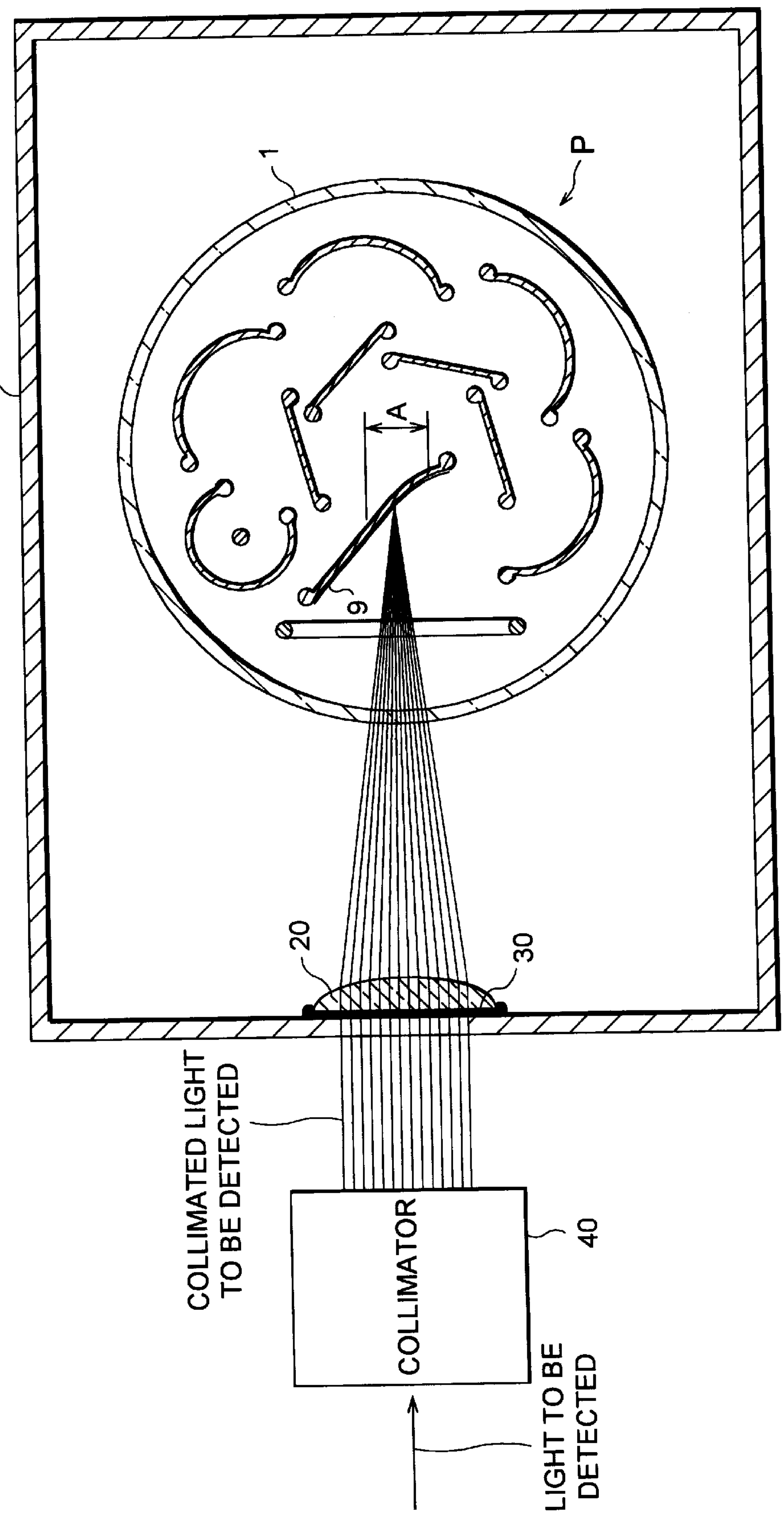

10
11
1
P
A
9
20
30
40
COLLIMATOR
COLLIMATED LIGHT
TO BE DETECTED
LIGHT TO BE
DETECTED

Fig.8

Fig.10

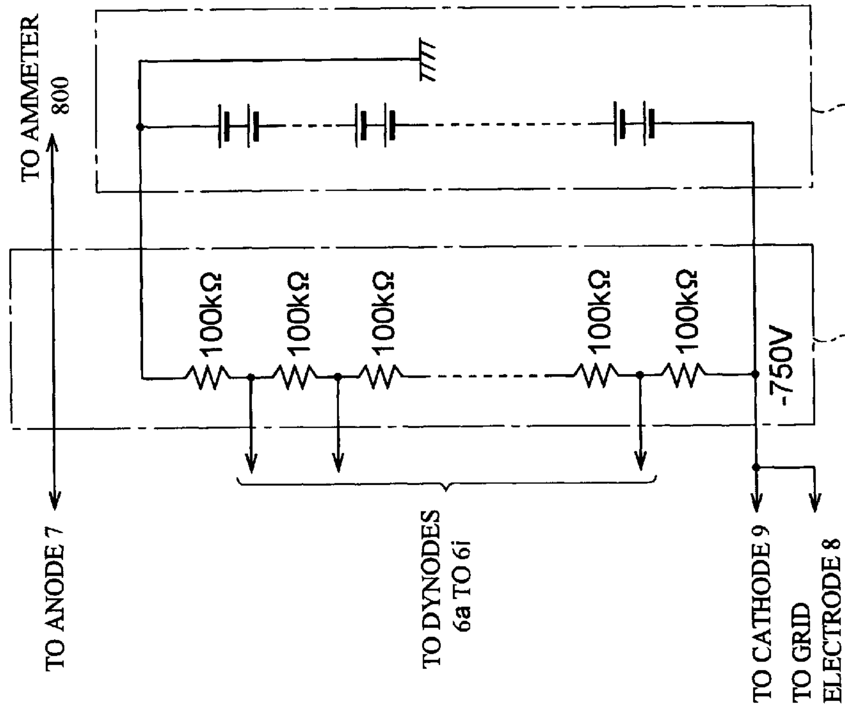

TO AMMETER 800
700
100kΩ
100kΩ
100kΩ
100kΩ
100kΩ
-750V
900
TO ANODE 7
TO DYNODES 6a TO 6i
TO CATHODE 9
TO GRID ELECTRODE 8

Fig.9

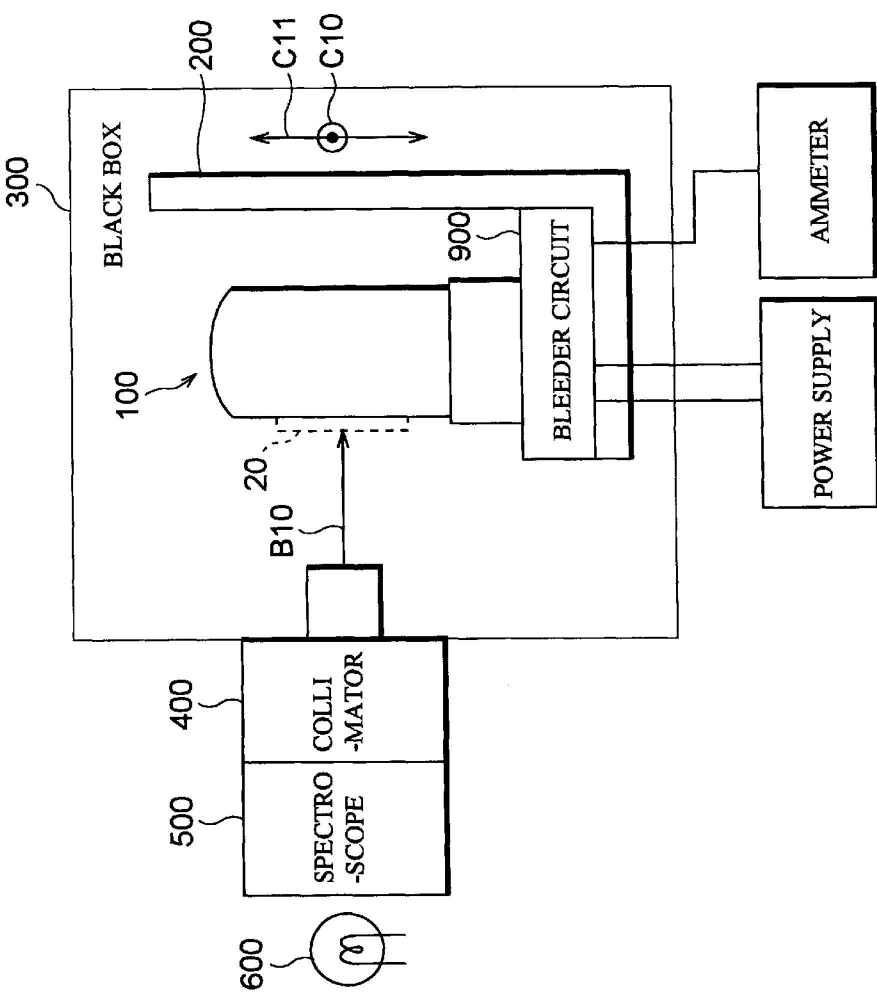

300
BLACK BOX
200
C11
C10
900
BLEEDER CIRCUIT
AMMETER
800
POWER SUPPLY
700
100
20
B10
400
COLLI -MATOR
500
SPECTRO -SCOPE
600

Fig.11

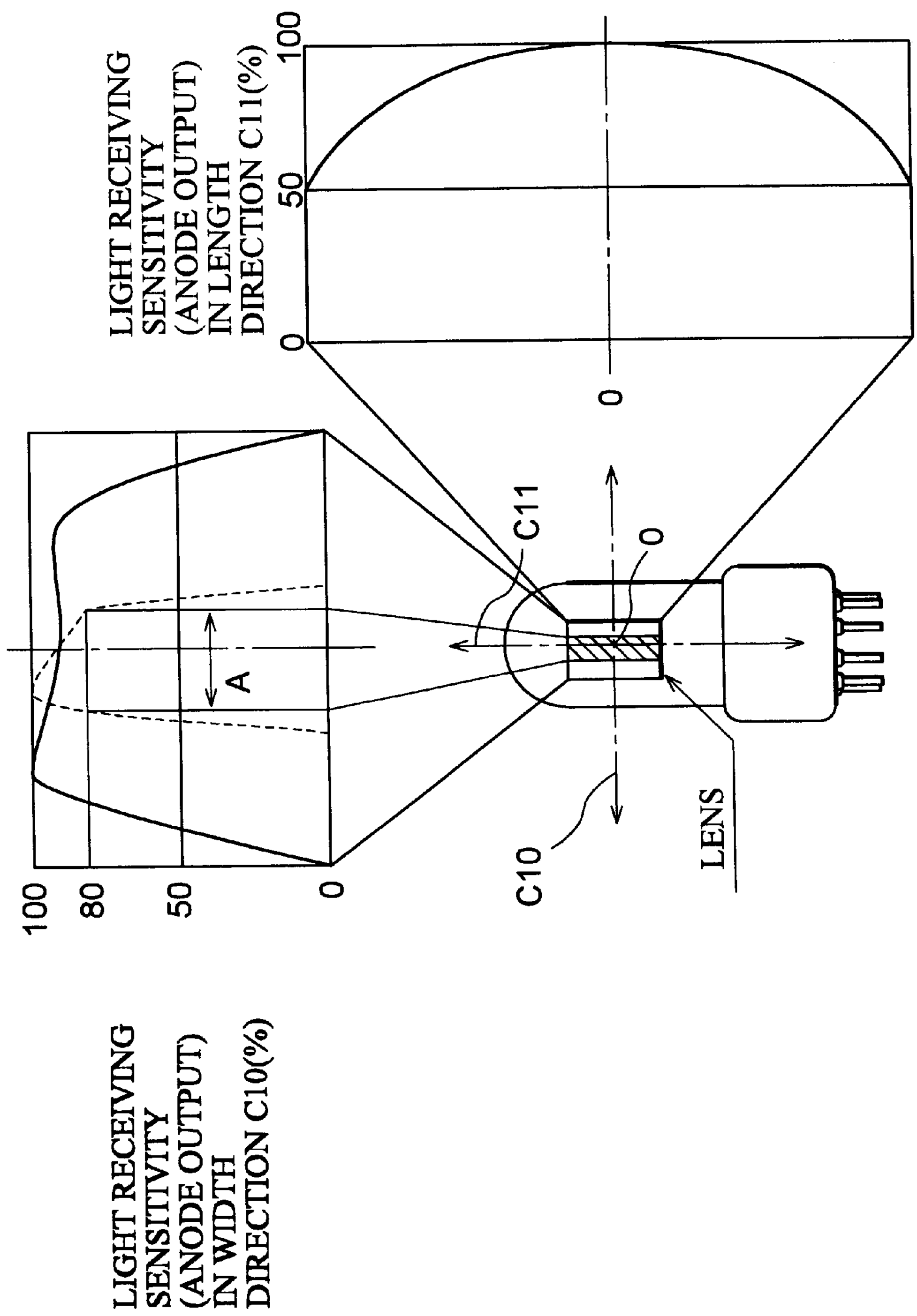
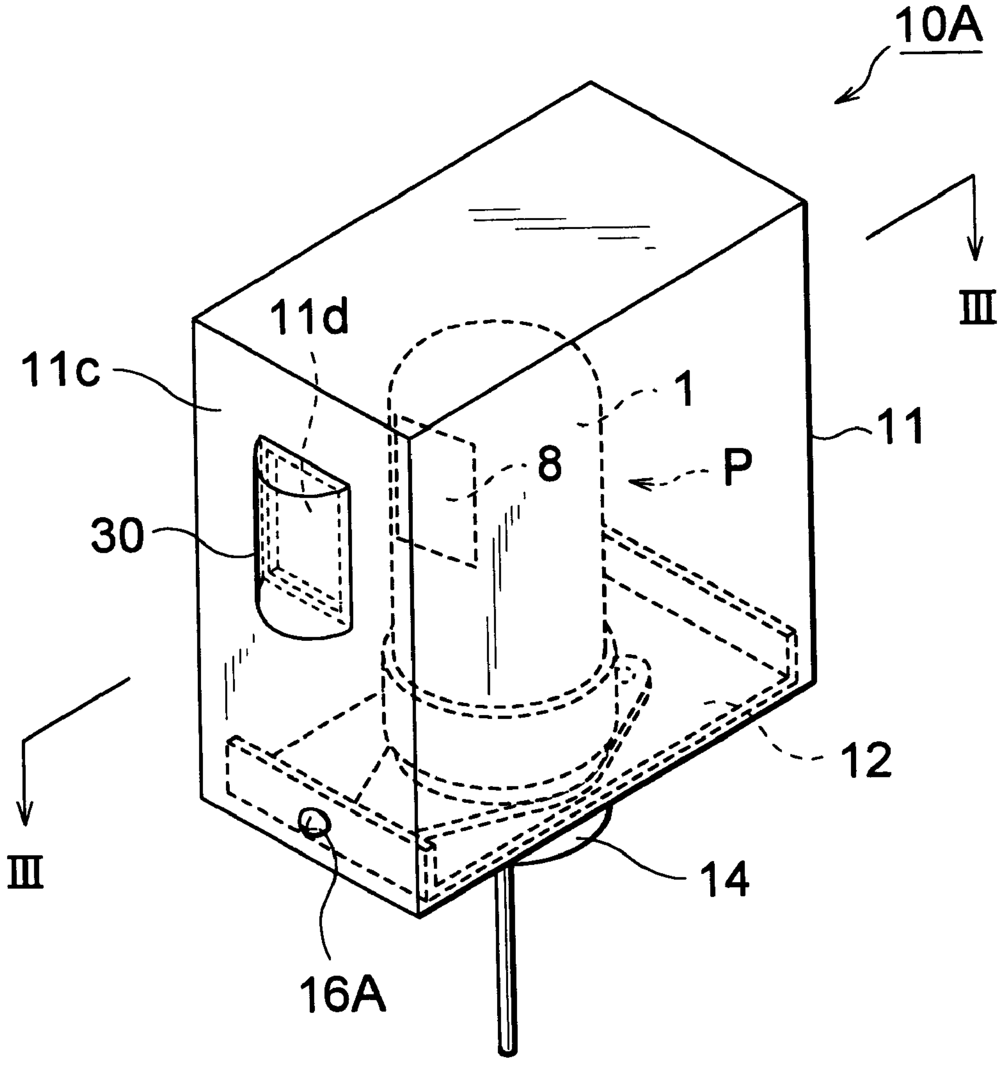

LIGHT RECEIVING SENSITIVITY (ANODE OUTPUT) IN LENGTH DIRECTION C11(%)
100
50
0
0
C11
0
A
100
80
50
0
C10
LENS
LIGHT RECEIVING SENSITIVITY (ANODE OUTPUT) IN WIDTH DIRECTION C10(%)

Fig. 12



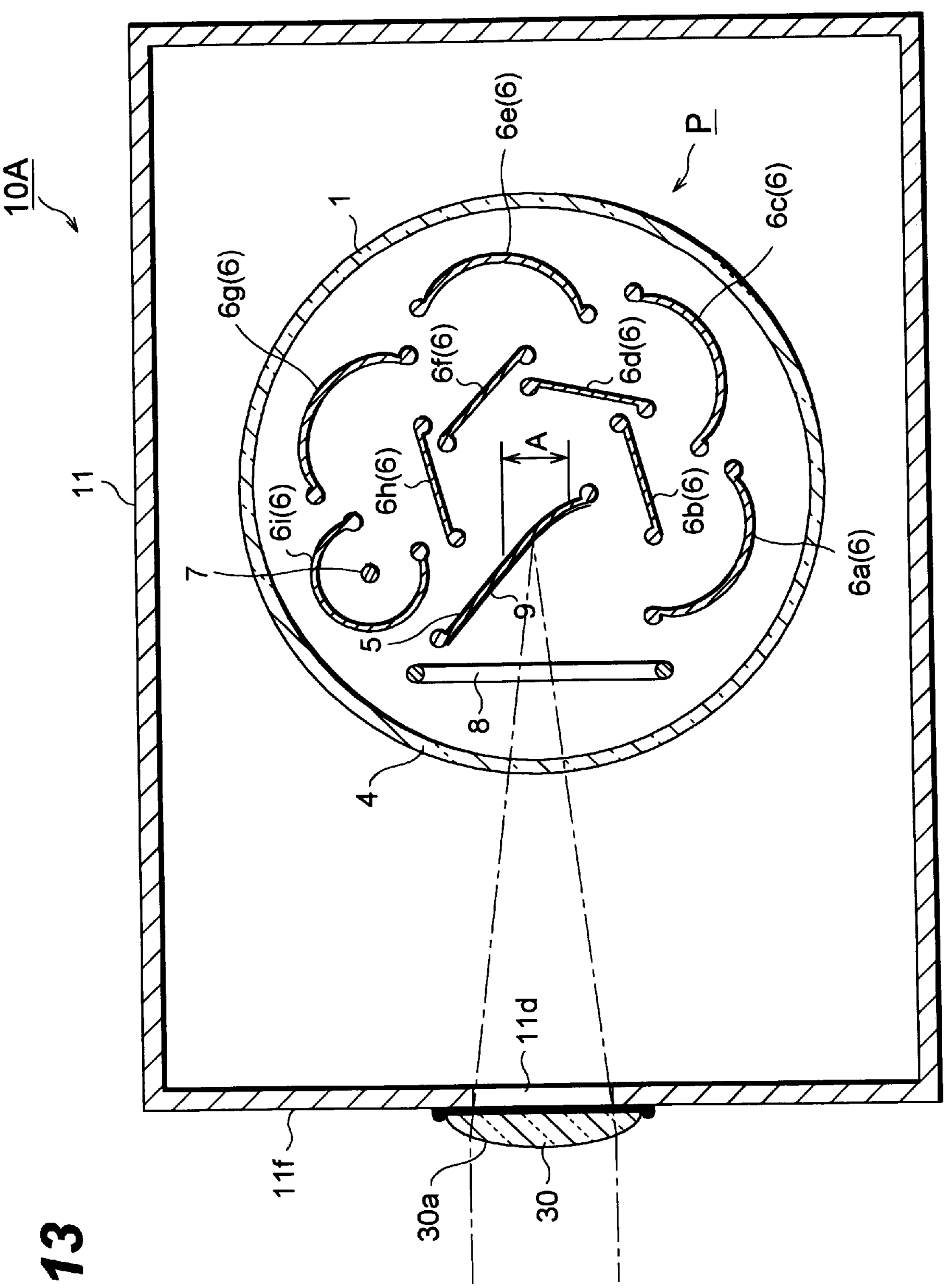
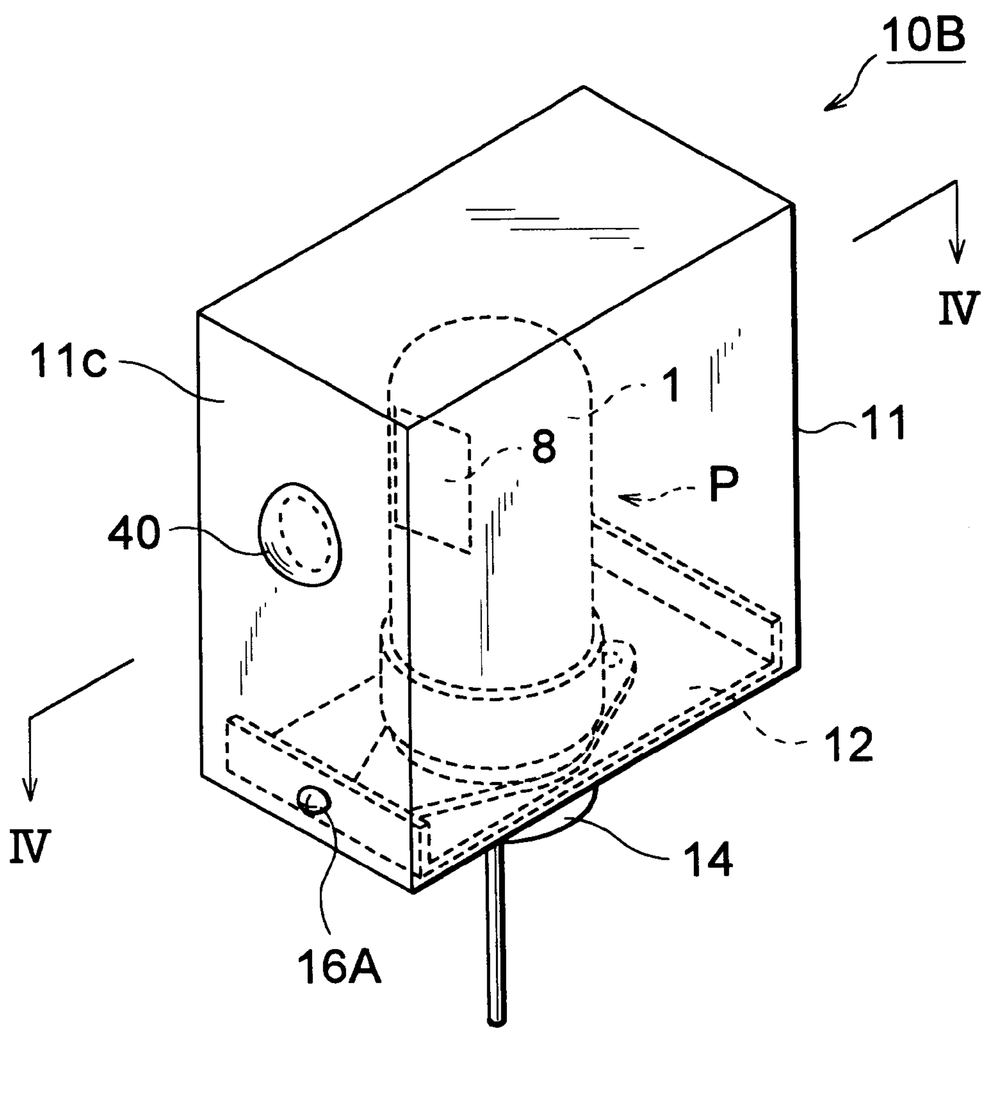

10A
11
1
P
6e(6)
6c(6)
6g(6)
6f(6)
6d(6)
A
6h(6)
6b(6)
6i(6)
6a(6)
7
9
5
8
4
11d
11f
30a
30

Fig.13

Fig.14



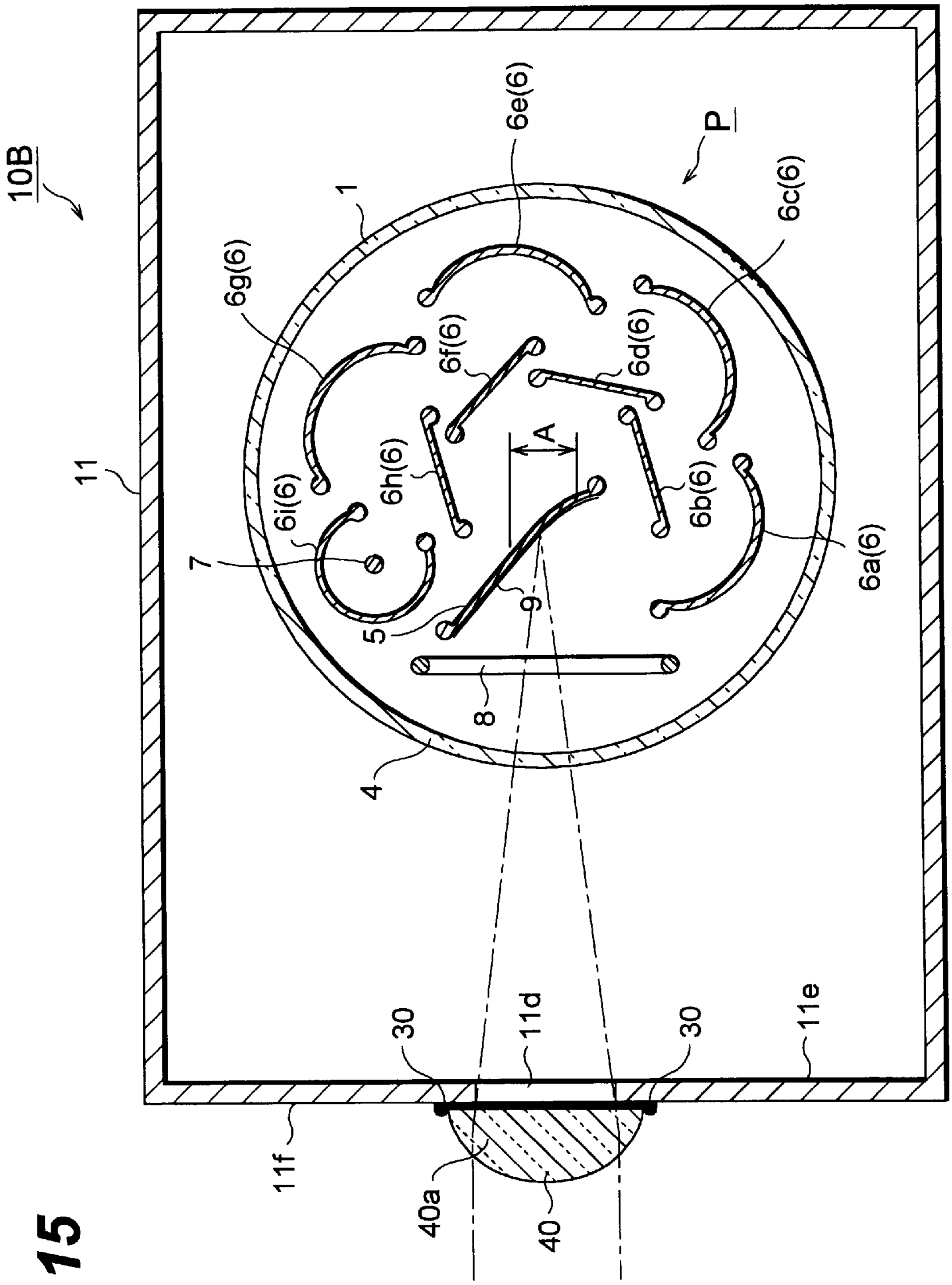

10B
11
1
P
6e(6)
6c(6)
6g(6)
6f(6)
6d(6)
A
6h(6)
6b(6)
6i(6)
7
9
5
6a(6)
8
4
30
11d
30
11e
11f
40a
40

Fig.15

Fig.16

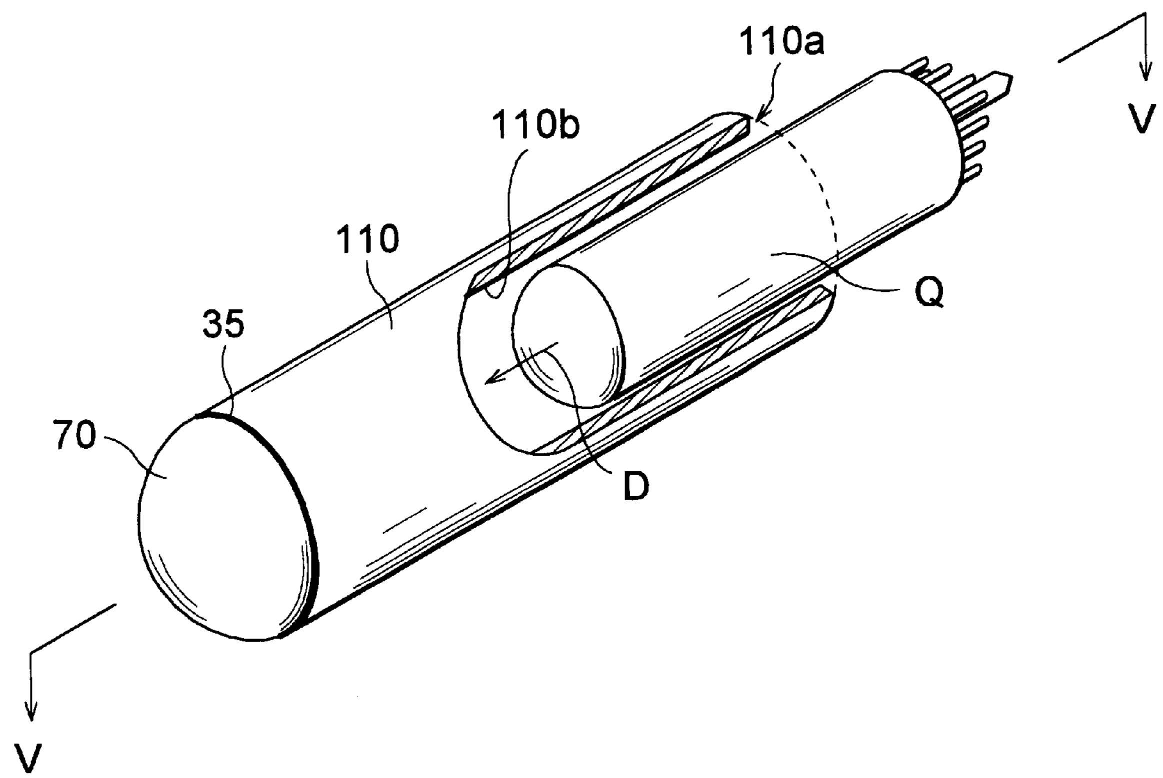
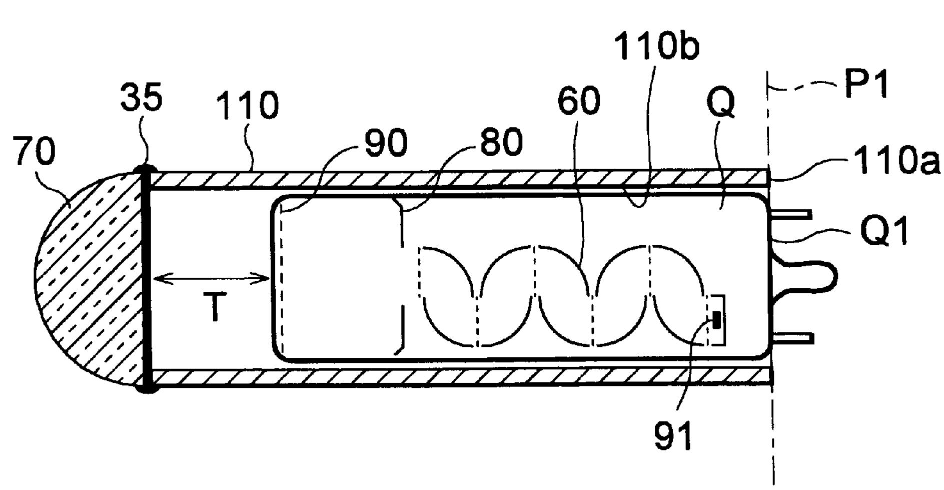


Fig.17



PHOTOMULTIPLIER WITH MAGNETIC SHIELDING CASE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a magnetic shielding case for protecting a photomultiplier from being influenced by magnetic fieldsin order to stabilize the output of the photomultiplier, and a light detecting apparatus which includes the magnetic shielding case and a photomultiplier housed within the magnetic shielding case.

2. Related Background Art

A conventional magnetic shielding case has, in general, the configuration shown in FIG. **1**. This magnetic shielding case **100** has a magnetic shielding main body **101** which is cylindrically formed of permalloy having a high permeability. Further, the magnetic shielding main body **101** is provided with a rectangular entrance window **105**, which faces a reflection type photocathode **104** disposed within a sealed glass envelope **103** of a side-on type photomultiplier **102**. Accordingly, incident light (light to be detected) transmitted through the entrance window **105** of the magnetic shielding case **100** impinges on the photocathode **104**, and photoelectrons emitted from the photocathode **104** are multiplied by an electron multiplying section **106** so as to be collected as an output signal at an anode **107**.

In general, a photomultiplier of a type in which the distance between the photocathode **104** and a dynode **106*a*** in the first stage is long are likely to be influenced by a magnetic field, whereby photoelectrons may deviate from their normal orbits under the influence of the magnetic field, thus lowering the gain. Accordingly, in order to keep the photomultiplier **102** from being influenced by external magnetic fields, the above-mentioned magnetic shielding case **100** has been utilized.

SUMMARY OF THE INVENTION

Having studied the conventional magnetic shielding case **100** and the light detecting apparatus, which includes the magnetic shielding case as well as the photomultiplier, the inventors have found the following problems.

Namely, since the entrance window **105** in the magnetic shielding case **100** is simply formed as an opening, magnetic fields directly influence the output of the photomultiplier **102**. Accordingly, in order to improve the magnetic shielding effect of the magnetic shielding case **100**, it has been proposed to reduce the size of the entrance window **105** in the magnetic shielding case **100** or enlarge the magnetic shielding case **100** itself so as to separate the photocathode **104** of the photomultiplier **102** and the entrance window **105** of the magnetic shielding case **100** from each other. When the photomultiplier **102** is separated from the entrance window **105**, however, the light incident on the photocathode **104** may incur a greater loss, thereby lowering the output signal intensity.

In order to overcome the problems mentioned above, it is an object of the present invention to provide a magnetic shielding case having a structure for improving the uniformity in light receiving sensitivity of the photomultiplier while maintaining a sufficient magnetic shielding function, and a light detecting apparatus including the same.

Specifically, the light detecting apparatus according to the present invention comprises, at least, a photomultiplier and a magnetic shielding case accommodating the photomultiplier. Here, the magnetic shielding case has a sufficient size so that photoelectrons from a photocathode are not influenced by magnetic fields through an entrance window. In particular, the magnetic shielding case comprises a housing for accommodating a photomultiplier, with a side face having a first opening (entrance window) for transmitting therethrough light to be detected which is directed to the photomultiplier; a lens element, transparent to the light to be detected, supported by the housing so as to close the first opening; and a positioning structure for placing the photomultiplier at a predetermined position in the housing so as to define a distance between a photocathode included in the photomultiplier and the lens element.

In the light detecting apparatus according to the present invention, the photomultiplier accommodated in the magnetic shielding case includes a side-on type photomultiplier having a reflection type photocathode inclined with respect to the direction of incidence of the light to be detected and a head-on type photomultiplier having a transmission type photocathode disposed substantially perpendicular to the light to be detected reaches. The lens element functions so as to restrict the incident area on the photocathode, where the light to be detected reaches. In order to reduce the influence of magnetic fields, the entrance window is disposed so as to be sufficiently separated from the photocathode of the photomultiplier accommodated in the magnetic shielding case. Accordingly, in order to obtain a desired light receiving sensitivity, it is important for the entrance window to be provided with the lens element.

In the case where the photomultiplier is a side-on type photomultiplier (i.e., in the case where it has a reflection type photocathode), the structure for positioning the magnetic shielding case comprises: a lid portion, attached to the housing, for defining, together with the housing, a space for accommodating the photomultiplier, the lid portion having an opening for defining a position where the photomultiplier is disposed; and a socket portion, attached to the lid portion so as to close the opening of the lid portion, for supporting the photomultiplier through the opening of the lid portion. Accordingly, by the magnetic shielding case having the thus described lid portion, the distance between the entrance window and the photocathode is accurately defined.

On the other hand, in the case where the photomultiplier is a head-on type photomultiplier (i.e., in the case where it has a transmission type photocathode), the housing comprises a second opening, opposing the entrance window, for accommodating the photomultiplier, and an inner wall of the housing and an opening end defining the second opening are included in the positioning structure. Also in this case, the distance between the entrance window and the photocathode is accurately defined.

When a side-on type photomultiplier is applied to the light detecting apparatus according to the present invention, the light to be detected that is incident on the lens element attached to the entrance window in the housing is collected at an effective region of the reflection type photocathode of the photomultiplier while being converged, and photoelectrons are generated from this effective region. The effective region is not only a highly sensitive area in the whole surface of the photocathode but also an area where stray electrons are less likely to occur, and is located near the dynode in the first stage. Since the place where the photoelectrons occur are restricted to a small area, i.e., effective region, fluctuations among times at which the respective photoelectrons occur are small. Also, since the photoelectrons are generated at places close to each other, fluctuations in electron transit time can be greatly reduced. Also, even when the position of light incident on the lens element is somewhat changed due to a small fluctuation in the position of a light source fluctuations in the output from the anode can become very small, since the light is collected at the effective region for the photoelectrons, together with little fluctuation in electron transit time . Further, even when the photocathode is not strictly positioned with respect to an object, light can be collected at an appropriate position of the photocathode due to the condensing action of the lens element. Consequently, it becomes easy to align the object and the photocathode with respect to each other in terms of optical axis. A little deviation in their optical axes hardly affects the uniformity in light receiving sensitivity. Such a condensing action is effective, in particular, for weak light such as chemiluminescence, bioluminescence, or fluorescence, thereby contributing to improvement in S/N. Further, even when the magnetic shielding case is enlarged so that the distance between the entrance window and the photocathode is increased in order to enhance the magnetic shielding effect, the loss in the light incident on the photomultiplier becomes so small that weak light can be detected easily even in a strong magnetic field due to the condensing action of the lens element.

In the case of the side-on type photomultiplier, the lens element preferably comprises a cylindrical lens. Here, the "cylindrical lens" refers to a lens having at least one surface formed like a part of a cylinder and yielding astigmatism such that a point of light extends into a line. When such a cylindrical lens is employed, the light to be detected can be collected in slit form on the effective region of the photocathode, thus elongating the form of the collected light on the photocathode in its longitudinal direction so as to match the long form of the photocathode. Accordingly, the form of the collected light can match the long form of the dynode in each stage, thus allowing the electron multiplying region of each dynode to be utilized efficiently. Also, it becomes unnecessary to perform an operation for inserting a slit plate between the object and the entrance window of the magnetic shielding case, and the axial alignment f the slit in the slit plate with the photocathode.

Also, in both cases of the side-on and head-on type photomultipliers, a hemispherical lens may be used as the lens element. Since the light to be detected can be collected onto the photocathode in spot form, the use of such a hemispherical lens is effective for detecting weak light in particular.

The magnetic shielding case further comprises the lid portion for closing the photomultiplier-inserting slot (second opening) formed in the housing. This lid portion has an opening for defining the position where the photomultiplier is disposed, and stem pins of the photomultiplier are coupled to the socket portion through this opening. When such a positioning structure is employed, the photomultiplier can be disposed at a predetermined position within the magnetic shielding case accurately and easily. Also, by means of the lid portion, the photomultiplier can be substantially closed within the magnetic shielding case, thus allowing the magnetic shielding effect to be further enhanced.

The present invention will be more fully understood from the detailed description given hereinbelow and the accompanying drawings, which are given by way of illustration only and are not to be considered as limiting the present invention.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will be apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing a cross-sectional configuration of a conventional light detecting apparatus which includes, at least, a photomultiplier and a magnetic shielding case accommodating it;

FIG. **2** is a perspective view showing a side-on type photomultiplier which is applicable to a light detecting apparatus according to the present invention;

FIG. **3** is a view showing a cross-sectional configuration, taken along line I—I, of the side-on type photomultiplier shown in FIG. **2**;

FIG. **4** is a perspective view showing a first embodiment of the light detecting apparatus according to the present invention to which a side-on type photomultiplier is applied (employing a cylindrical lens as its lens element);

FIG. **5** is a perspective view showing a configuration of a lens element made of a plastic material applicable to the light detecting apparatus shown in FIG. **4**;

FIG. **6** is a view for explaining assembling steps of the first embodiment of the light detecting apparatus according to the present invention;

FIG. **7** is a sectional view, taken along line II—II, of the first embodiment of the light detecting apparatus shown in FIG. **4**;

FIG. **8** is a view for explaining a function of the lens member employed in the light detecting apparatus according to the present invention, which corresponds to the sectional view of the first embodiment taken along line II—II in FIG. **4**;

FIG. **9** is a view showing a measurement system for measuring a sensitivity characteristic of the light detecting apparatus according to the present invention;

FIG. **10** is a view showing a configuration of a bleeder circuit and power supply in the measurement system of FIG. **9**;

FIG. **11** is a graph showing respective anode outputs of side-on type photomultipliers receiving the light to be detected through and without a lens member measured by the measurement system shown in FIG. **9**;

FIG. **12** is a perspective view showing a first modified example of the first embodiment of the light detecting apparatus according to the present invention (in which the lens element (cylindrical lens) is attached to the magnetic shielding case in a manner different from that of FIG. **4**);

FIG. **13** is a sectional view, taken along line III—III, of the light detecting apparatus shown in FIG. **12**;

FIG. **14** is a perspective view showing a second modified example of the first embodiment of the light detecting apparatus according to the present invention (in which a hemispherical lens is employed as the lens element);

FIG. **15** is a sectional view, taken along line IV—IV, of the light detecting apparatus shown in FIG. **14**;

FIG. **16** is a view for explaining assembling steps of a second embodiment of the light detecting apparatus according to the present invention; and

FIG. **17** is a sectional view, taken along line V—V, of the light detecting apparatus shown in FIG. **16**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, preferred embodiments of the magnetic shielding case a light detecting apparatus which includes the magnetic shielding case and a photomultiplier housed within the magnetic shielding case according to the present invention will be explained in detail with reference to FIGS. **2** to **17**.

FIG. **2** is a perspective view showing a side-on type photomultiplier to be accommodated in the magnetic shielding case according to the present invention. FIG. **3** is a sectional view, taken along line I—I, of the side-on type photomultiplier shown in FIG. **2**. The side-on type photomultiplier P shown in these drawings comprises a sealed envelope **1** which is transparent to light. This sealed envelope **1** is formed as a transparent cylindrical whose upper and lower ends are closed, while comprising borosilicate glass, UV glass, silica glass, or the like. In the sealed envelope **1**, a pair of insulator substrates **2***a* and **2***b* made of ceramics or the like are disposed, while various kinds of electrodes are supported between the pair of insulator substrates **2***a* and **2***b*. Secured to the bottom portion of the sealed envelope **1** is a pin base **3** made of a resin. This pin base **3** is provided with a plurality of stem pins **3***a,* by which the various kinds of electrodes are lead to the outside.

As shown in FIGS. **2** and **3**, supported by the pair of insulator substrates **2***a* and **2***b* therebetween are a reflection type photocathode **9** inclined by a predetermined angle with respect to the incident direction A**10** of light to be detected; an electron multiplying section **6** comprising a plurality of stages of dynodes **6***a* to **6***i* for successively multiplying a photoelectron emitted from the photocathode **9**; and an anode **7** for collecting thus multiplied electron as an output signal. Further disposed between the light incident portion **4** and the photocathode **9** is a grid electrode **8** for securely guiding the photoelectron emitted from the photocathode **9** into the dynode **6***a* of the first stage. This grid electrode **8** is set to the same potential as the photocathode **9**. Also, the photocathode **9** is formed on an electrode plate **5** and faces the light incident portion **4** of the sealed envelope **1** across the grid electrode **8**.

FIGS. **4** and **6** show a magnetic shielding case **10** (first embodiment) for protecting the above-mentioned photomultiplier P against external magnetic fields, and a light detecting apparatus including the same. This magnetic shielding case **10** comprises a cuboidal box-shaped housing (magnetic shielding main body) **11** made of permalloy having a high permeability. The upper and lower ends of the housing **11** are respectively provided with a rectangular top plate **11***a* and an open rectangular photomultiplier-inserting slot **11***b*. Also, a through screw hole **15** is formed at the lower end of the housing **11** so as to be utilized when a set screw **16**A secures a lid portion **12** which will be explained later.

The magnetic shielding case **10** further comprises the lid portion **12**, shaped like a plate, for closing the photomultiplier-inserting slot **11***b*. The lid portion **12** is made of permalloy having a high permeability. The lid portion **12** has a bottom plate **12***a* substantially matching the plane including the photomultiplier-inserting slot **11***b*. Both ends of the bottom plate **12** are provided with bent portions abutting to the lower end of an inner wall face **11***e* (see FIG. **6**) of the housing **11**. Each bent portion **12***b* is provided with a tapped hole **17**. When each tapped hole **17** is aligned with its corresponding through screw hole **15**, the lid portion **12** can be secured to the housing **11** with the set screw **16**A. Also, the bottom plate **12***a* is provided with a through screw hole **18**, which is utilized when a set screw **16**B secures a socket portion **14** which will be explained later.

The magnetic shielding case **10** further comprises the socket portion **14** that fits into a circular socket opening **13** formed at the center of the bottom plate **12***a*. The top part of the socket portion **14** is provided with electric connecting holes **14***a* for respectively receiving the stem pins **3***a* of the photomultiplier P. The socket portion **14** has flanges **14***b* radially extending from its peripheral surface. Each flange **14***b* has a tapped hole **19**. Accordingly, when each tapped hole **19** is aligned with its corresponding through screw hole **18** of the lid portion **12** while each flange **14***b* is butted against the rear face of the bottom plate **12***a,* the socket portion **14** can be secured to the lid portion **12** with the set screw **16**B.

In the magnetic shielding case **10**, as shown in FIGS. **4** and **7**, a front wall **11***c* of the housing **11** is provided with a rectangular entrance window **11***d* facing the photocathode **9** through the light incident portion **4** of the sealed envelope **1**. A condenser lens **20** (lens element) made of glass is secured to the housing **11**. This condenser lens **20** includes a cylindrical lens having a cylindrically-curved lens surface **20***a*. The condenser lens **20** is secured to the inner wall face **11***e* by means of an adhesive such that the lens surface **20***a* faces the photomultiplier P. Accordingly, the cylindrical lens **20** is prevented from projecting from an outer wall face **11***f* of the housing **11**, and the lens surface **20***a* is kept from being damaged during the handling of the magnetic shielding case **10**. Here, such a lens element may be made of a plastic material as shown in FIG. **5**. The plastic lens element **50** of FIG. **5** has side-cut surfaces **51** and **52** that are formed by cutting both side edges of the lens **50**.

In the following, assembling steps for the above-mentioned magnetic shielding case **10** will be explained briefly. First, as shown in FIG. **6**, the housing **11** to which the cylindrical lens **20** has been completely bonded and secured is prepared. Then, the stem pins **3***a* of the photomultiplier P are respectively inserted into the electric connecting holes **14***a* in the socket portion **14** secured to the lid portion **12**, whereby the photomultiplier P is secured to the lid portion **12**. Thereafter, the photomultiplier P is inserted into the housing **11** through the photomultiplier-inserting slot **11***b,* and the tapped holes **17** of the lid portion **12** are aligned with their corresponding through screw holes **15**. Thereafter, the set screws **16**A are fastened into their corresponding through screw holes **15** and tapped holes **17**, whereby the lid portion **12** is secured to the housing **11**, thus completing the operation for attaching the photomultiplier P to the magnetic shielding case **10**. By this operation, the photomultiplier P is accurately positioned.

Further, the radius of curvature of the lens surface **20***a* of the cylindrical lens **20** is selected such that, as shown in FIG. **8**, the light incident on the cylindrical lens **20** substantially forms a focal point in an effective region A of the photocathode **9** of the photomultiplier P. When the cylindrical lens **20** like this is utilized, the light to be detected can be collected into a slit form on the effective region A of the photocathode **9**. Thus, the form of collected light on the photocathode **9** is elongated in its longitudinal direction so as to match the long form of the photocathode **9**. Accordingly, when the part generating photoelectrons is formed like a long slit, the long electron multiplying region produced by each of the dynodes **6***a* to **6***i* can effectively be utilized.

As shown in FIG. **8**, the light detecting apparatus according to the present invention may further comprise a collimator **40** for collimating the light to be detected.

FIG. **9** is a view showing a measurement system for measuring the uniformity in light receiving sensitivity of a side-on type photomultiplier which is an object to be measured.

The measurement system shown in FIG. **9** comprises, at least, a light source **600**; a spectroscope **500** for selecting a light component with a predetermined wavelength from the light emitted from the light source **600**; a collimator **400** for collimating the light component selected by the spectroscope **500**; a black box **300** accommodating a photomultiplier **100** (including photomultipliers with and without the lens element **20**) which is the object to be measured; a stage **200** for relatively moving the object to be measured **100** with respect to a beam B**10** emitted from the collimator **400**; a power supply **700** for supplying a desired voltage to the object to be measured **100**; a bleeder circuit **900** for dividing the voltage supplied from the power supply **700**; and an ammeter **800** for detecting the output signal obtained from the anode of the object to be measured **100**.

Here, the stage **200** on which the object to be measured **100** is mounted and the bleeder circuit **900** are accommodated in the black box **300**. The stage **200** moves the object to be measured **100** in the directions indicated by depicted arrows C**10** (directions perpendicular to the paper surface) and in the directions indicated by depicted arrows C**11** (directions orthogonal to the directions indicated by C**10**).

As shown in FIG. **10**, the bleeder circuit **900** comprises a plurality of resistors connected in series, thereby dividing the voltage supplied from the power supply **700**.

Here, the above-mentioned effective region A is, in the whole surface of the photocathode **9**, not only an area which has a high sensitivity but also an area where stray electrons are less likely to occur. This effective region A is an area near the dynode **6***a* of the first stage, is positioned on the inner side of the sealed envelope **1**, and is far from the grid electrode **8** having the same potential. Namely, as can also be seen from FIG. **8**, the effective region A refers to, in the photocathode **9**, an area which extends from near the center portion toward the dynode **6***a* of the first stage where the light receiving sensitivity (anode output) in the width directions is not lower than 80%. Here, there are also cases where the effective area A is determined as an area in which the light receiving sensitivity in the width directions is not lower than 90%.

Next, the inventors measured changes in light receiving sensitivity between photomultipliers with and without a condenser lens by using the measurement system shown in FIGS. **9** and **10**.

Specifically, the wavelength of the light to be measured was 400 nm, whereas its spot diameter was 1 mm. The condenser lens was a cylindrical lens having a width (in the directions indicated by C**10** in FIG. **9**) and a length of 28 mm (in the directions indicated by C**11** in FIG. **9**). Here, the radius of curvature of the lens surface **20***a* of the cylindrical lens used was designed such that the collimated light to be detected could reach into the effective region A.

The scanning pitch of the spot light (having a wavelength of 400 nm and a spot diameter of 1 mm) in the width directions C**10** was 1 mm. On the other hand, the scanning pitch of the spot light (having a wavelength of 400 nm and a spot diameter of 1 mm) in the length directions C**11** was also 1 mm. By connecting a plurality of 100-kΩ resistors in series, the bleeder circuit **900** equally divides the applied voltage. An output terminal of the anode **7** is connected to the ammeter **800**, whereas a voltage of −750 V is applied to the photocathode **9**.

FIG. **11** shows graphs each showing a relationship between the incident position of the spot light and the anode output measured under the condition mentioned above. In these graphs, solid and dashed lines respectively indicate measured results of the photomultipliers with and without the condenser lens.

As can be seen from the upper-side graph of FIG. **11**, the photomultiplier without the condenser lens can hardly measure the light to be detected incident on the outside of the effective region A. In the photomultiplier with the condenser lens, by contrast, a wide range of the light to be detected is guided by the condenser lens along the width directions C**10** into the effective region A, thereby improving the uniformity in light receiving sensitivity.

On the other hand, as can be seen from the right-side graph of FIG. **11**, due to the forms of the photocathode **9** and dynodes **6***a* to **6***i*, no remarkable difference could be found in the light receiving sensitivity along the length directions C**11** between the cases with and without the condenser lens.

The present invention should not be restricted to the first embodiment mentioned above. In a first modified example shown in FIGS. **12** and **13**, as with the first embodiment, a condenser lens **30** made of glass is secured to the front wall **11***c* of a magnetic shielding case **10**A. The condenser lens **30** is secured to the housing **11** so as to close the rectangular entrance window **11***d* disposed at a position facing the photocathode **9** through the light incident portion **4** of the sealed envelope **1**. Also, the condenser lens **30** is a cylindrical lens having a cylindrically-curved lens surface **30***a*. The condenser lens **30** is secured to the outer wall face **11***f* of the housing **11** by means of an adhesive such that the lens surface **30***a* is directed to the outside of the housing **11**. Accordingly, the condenser lens **30** can be bonded to the housing **11** from the outside, thus facilitating the positioning and securing of the condenser lens **30**. Here, in FIGS. **12** and **13**, constituents identical or equivalent to those in the magnetic shielding case **10** of the above-mentioned first embodiment are referred to with marks identical thereto without their explanations being repeated.

Further, FIGS. **14** and **15** show a second modified example of the above-mentioned first embodiment. In this modified example, as with the first embodiment, a condenser lens **40** made of glass is secured to the housing **11** so as to close the rectangular entrance window **11***d* disposed at the front wall **11***c* of a magnetic shielding case **10**B. This condenser lens **40** is a hemispherical lens having a spherically-curved lens surface **40***a*. This hemispherical lens **40** is secured to the outer wall face **11***f* of the housing **11** by means of an adhesive such the lens surface **40***a* is directed to the outside of the housing **11**. Accordingly, the condenser lens **40** can be bonded to the housing **11** from the outside, thus facilitating the operations for positioning and securing the condenser lens **40**.

The radius of curvature of the lens surface **40***a* in the hemispherical lens **40** is selected such that the light incident on the hemispherical lens **40** substantially forms a focal point in the effective region A of the photocathode **9**. Also, when the hemispherical lens **40** is utilized, the collimated light to be detected can be collected into a spot-like form on the effective region A of the photocathode **9**. Selected as the location of this spot-like collected light portion is the center part on the effective region A where the light receiving sensitivity (anode output) in the length directions is particularly high (See FIG. **11**). When the light is thus substantially collected like a point, very weak light to be measured can securely be detected.

Here, the hemispherical lens **40** may be secured to the inner wall face **11***e* of the housing **11**. In FIGS. **14** and **15**, constituents identical or equivalent to those in the magnetic shielding case **10** of the above-mentioned first embodiment are referred to with marks identical thereto without their explanations being repeated.

The magnetic shielding case of the present invention should not be restricted to the above-mentioned examples, and the housing **11** may also have a cylindrical or prism-like form. Also, within the magnetic shielding case, the photomultiplier P may be positioned not only at the center of the housing **11** but also on its inner side farthest from the entrance window **11***d*. Further, although preferably made of glass, the condenser lens may be made of plastic.

FIGS. **16** and **17** show a second embodiment of the magnetic shielding case according to the present invention, and the light detecting apparatus, which includes the magnetic shielding case and the photomultiplier housed within the magnetic shielding case. In this embodiment, a head-on type photomultiplier Q having a transmission type photocathode is employed. Also, its housing (magnetic shielding main body) **110** has a cylindrical form. Secured to one of the openings of this housing **110** by means of an adhesive **35** is a hemispherical lens **70**, whereas the photomultiplier Q is accommodated into the housing **110** through the other opening along the direction indicated by arrow D in FIG. **16**.

As shown in FIG. **17**, the head-on type photomultiplier Q comprises a transmission type photocathode **90**, a focusing electrode **80**, an electron multiplying section **60**, and an anode **91**.

In the magnetic shielding case of the second embodiment, in order to define the distance between the photomultiplier Q and the hemispherical lens **70**, an opening end **110***a* of the housing **110** functions as a positioning structure. Namely, when the photomultiplier Q is secured into the housing **110** such that a plane **P1** including the opening end **110***a* is made flush with the bottom surface **Q1** of the photomultiplier Q, the influence of magnetism resulting from the existence of the opening through which light enters can be effectively suppressed. Therefore, the inner wall **110***b* and the opening end **110***a* are included in the positioning structure.

As explained in the foregoing, in accordance with the present invention, the housing has an entrance window at a position facing the light incident portion of the sealed envelope, whereas a condenser lens is disposed so as to close this entrance window. Since this condenser lens can be disposed at a position by which incident light can be collected onto an effective region of the photocathode of the photomultiplier having a high sensitivity, the uniformity in light receiving sensitivity of the photomultiplier can be improved, and the magnetic shielding effect enhanced. Also, the present invention's very remarkable advantages lie in that the uniformity in light receiving sensitivity of the photomultiplier is dramatically improved by a very simple structure in which a condenser lens is bonded and secured to a housing having a magnetic shielding effect.

From the invention thus described, it will be obvious that the invention may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

The basic Japanese Application No. 8-237018 (237018/1996) filed on Sep. 6, 1996 is hereby incorporated by reference.

What is claimed is:

1. A light detecting apparatus, comprising:

a photocathode provided to receive light from a light emitting source originating externally to said light detecting apparatus and to emit photoelectrons in accordance with the light detected;

an electron multiplying portion provided to multiply the photoelectrons from said photocathode;

an anode provided to collect electrons from said electron multiplying portion;

an envelope accommodating said photocathode, said electron multiplying portion and said anode; and

a magnetically-shielding structure having:

a housing made of a material magnetically shielding at least said photocathode while accommodating said envelope, said housing having a first opening for passing through the light to be detected toward said photocathode;

a lens element transparent to the light to be detected, supported by said housing so as to close said first opening and to direct light to said photocathode; and

a positioning structure provided so as to place said envelope at a predetermined position so as to define a distance between said photocathode and said lens element.

2. A light detecting apparatus according to claim **1**, wherein said positioning structure includes:

a lid portion, made of a material magnetically shielding at least said photocathode, attached to said housing, said lid portion defining a space accommodating said envelope together with said housing, and having an opening defining a position where said photocathode in said envelope is disposed; and

a socket portion attached to said lid portion so as to close the opening of said lid portion, said socket portion supporting said envelope through the opening of said lid portion.

3. A light detecting apparatus according to claim **1**, wherein said lens element includes a cylindrical lens.

4. A light detecting apparatus according to claim **1**, wherein said lens element includes a hemispherical lens.

5. A light detecting apparatus according to claim **1**, wherein said housing comprises a second opening arranged so as to face said first opening.

6. A light detecting apparatus according to claim **5**, wherein said lens element includes a hemispherical lens.

7. A light detecting apparatus, comprising:

a photocathode provided to receive light from a light emitting source originating externally to said light detecting apparatus and to emit photoelectrons in accordance with the light detected;

an electron multiplying portion provided to multiply the photoelectrons from said photocathode;

an anode provided to collect electrons from said electron multiplying portion;

an envelope accommodating said photocathode, said electron multiplying portion, and said anode; and

a magnetically shielding structure having:

a housing made of a material magnetically shielding at least said photocathode while accommodating said envelope, said housing having a first opening for passing through the light to be detected toward said photocathode;

a lens element transparent to the light to be detected, and being supported by said housing so as to close said first opening, said lens element having a convex portion directed inward of said housing and toward said photocathode; and

a positioning structure provided so as to place said envelope at a predetermined position so as to define a distance between said photocathode and said lens element.

8. A light detecting apparatus, comprising:

a photocathode provided to receive light, said light originating externally to said light detecting apparatus and to emit photoelectrons in accordance with the light detected;

an electron multiplying portion provided to multiply the photoelectrons from said photocathode;

an anode provided to collect electrons from said electron multiplying portion;

an envelope accommodating said photocathode, said electron multiplying portion and said anode; and

a magnetically-shielding structure having:

a housing made of a material magnetically shielding at least said photocathode while accommodating said envelope, said housing having a first opening for passing through the light to be detected toward said photocathode;

a lens element transparent to the light to be detected, supported by said housing so as to close said first opening and to direct light to said photocathode; and

a positioning structure provided so as to place said envelope at a predetermined position so as to define a distance between said photocathode and said lens element.

* * * * *